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A PATENT ANALYSIS OF THE CAMBRIDGE INKJET CLUSTER

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A patent analysis of the Cambridge inkjet printing cluster

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Abstract

This paper investigates the Cambridge inkjet printing (IJP) cluster through the analysis of patents as a proxy indicator of core competences. The level of technological sophistication of IJP companies can be determined through patent statistics (Duysters and Hagedoorn, 2000). According to Patel and Pavitt (1991) and Cantwell and Hodson (1991) patents are an acceptable indicator of research output and technological competence. Although they are subject to debate regarding their usefulness (Cohen and Levin, 1989; Grilliches, 1990; Archibugi, 1992) they enable the comparison of technological performance (Pavitt, 1988, Acs and Audretsch, 1989) of IJP companies. A case study analysis has been undertaken of patenting activities of the population of IJP companies in Cambridge. The results of the study show that patents are a proxy measure of competence even during periods of economic cycles and the patent data indicates a steady increase in competence.

Key words: patents, core competences, inkjet printing, Cambridge, cluster

Introduction

A cluster of Cambridge firms that have achieved global expansion on the basis of a common set of technologies, spinning out of the technical design consultancy Cambridge Consultants Limited (CCL), are the Inkjet Printing companies which include Domino Printing Sciences, Elmjet, Biodot, Xennia, Imaje, Willett, Linx, Xaar and Inca Digital Printers. With regard to the genealogy of these inkjet printing companies the two exceptions to being located in Cambridge are Imaje in France and Willett in Corby. In the year 2000 the ink jet printing firms employed more than 3,000 directly and their custom provided further employment in printed circuit boards (PCBs) and precision engineering firms in the regions. The companies were dominant in international markets for non-impact product identification, which is a smaller market than the larger market for small business and desktop ink jet printing. Combined revenues for the firms were estimated at £500m in around 2000[1]. Since the production chain is international ink jet printing firms source jewels from Switzerland, pumps from the United States (US) and precision components from many other sources, but they also share some of the local suppliers. The companies do not formally collaborate nor do they regularly supply each other although there is frequent informal interaction and linkages resulting from their common origins and the mobility of staff. Ink Jet Printing (IJP) customer companies in the Cambridge area have helped local PCB and precision engineering suppliers to upgrade their performance and these contractors have then been able to help other customers in the area to upgrade their products and production processes. Although IJP clients have

[1] Calculations by Alan Barrell, former CEO of Domino Printing Sciences and Willetts.

remained an important source of custom for local suppliers sub-assemblies have come to be sourced internationally as the industry has matured. Through the experience of Domino Printing Sciences, the role of leading companies in production networks has been confirmed. Domino grew to over 1,000 employees and provided custom for suppliers in the East of England including Hansatech in King's Lynn. The IJP companies draw upon a local labour market skilled in the relevant competences. When IJP technologies were adopted by new entrants who developed advanced materials such as light emitting polymers (Cambridge Display Technology and Plastic Logic) they were able to hire professional staff with experience in the local IJP cluster, demonstrating the role of job mobility in the diffusion of competence in the area. At technician and operator levels, however, IJP companies found it difficult to recruit skilled personnel at competitive rates. Videojet (who acquired Elmjet) moved out of the Cambridge area after being acquired by Danaher, with closure of the local site, while the manufacturing function of Xaar was relocated to Sweden after a merger.

Inkjet-printing is the collective name for a variety of different techniques to generate droplets of ink, which are propelled towards a surface to produce a printed mark. These techniques have been applied in a wide range of industries and markets that can benefit from the key features of inkjet-printing which are that it provides: non-impact / contact process for printing; infinitely variable output on demand; and high speed and high resolution. For the purposes of this overview, the industry is divided between the products developed for industrial applications (marking, labelling and coding for production lines), printing applications (commercial printing) and home and office equipment applications (desktop printing). This discussion will focus largely on the first two applications.

The core technologies that underpin industrial inkjet-printing are fluid dynamics and information technology. Discoveries made in the eighteenth century in France relating to the interaction of static electricity on a drop stream can be regarded as forming the first link in the chain of advancement that resulted in the development of inkjet-printing. However, it was not until the 1960s that Richard Sweet at Stanford University patented a method for deflecting individual droplets of ink in a continuous stream. The further development of this technology led to the first continuous inkjet printer, the 'Model 9600' produced by the US firm A.B. Dick Inc in the late 1960s.

At the start of the 1970s, Cambridge Consultants Ltd. (CCL), a University spin-out, in the U.K. were working on various continuous inkjet-printing technologies funded by the chemical multinational ICI. CCL was contracted to develop inkjet technologies for printing textiles at high speed, over wide widths and in colour. ICI withdrew from this project a few years later upon the advice of external consultants when it became clear that the level of complexity required to achieve their quality and cost targets had been underestimated. However, engineers at CCL (in particular Graeme Minto) saw the potential of inkjet-printing and bought the rights to use the technologies. They continued to build their knowledge and expertise in this area. Graeme Minto obtained support from CCL to spin out the technology in a new company founded in 1978. Domino was an independent start up which took over the IP in the technology from ICI and CCL. Domino Printing Sciences went on to be one the most successful businesses in the labelling and coding industry.

The technologies that are combined to form an inkjet-printing system are sensitive to their environment. Fine nozzles spray over 64,000 droplets of ink per second that are then deflected by a precise electrical charge and targeted at a specific point on an item on a fast-moving production line. Inks are required to remain fluid until the droplets hit the target whereupon they need to adhere and dry as rapidly as possible. Extensive resource is applied to understanding the chemistry of the inks and the physics of the print-heads to ensure that the inkjet systems work even in the hostile environment of a fast-moving assembly line. In addition, selling inks can make a substantial contribution to revenues over the lifetime of a printer.

Cambridge inkjet printing companies have been dependent on developing and delivering high quality and reliable products, with efficient after sales support and have had to ensure that consumables used within the system are of the right quality. Scale up challenges have been met which is unusual for UK companies. A reliable system for applying variable information for high speed production processes, such as drink manufacturers with production line runs of about 2,000 cans a minute, is essential.

Technological scale up is well illustrated by the growth of patents for the Cambridge Inkjet Printing companies. Figure 1 shows cumulative patents for the companies from 1985 to 2008. From these it can be seen that Domino Printing Sciences is the largest of the companies in terms of employees, turnover and profit and based on these measures outperforms the other companies to a significant margin. Its competitor, Linx, comes second with regard to these measures although this is not the case with patents where Domino has filed the second most patents and Linx the fourth most with the Xaar Group filing the most.

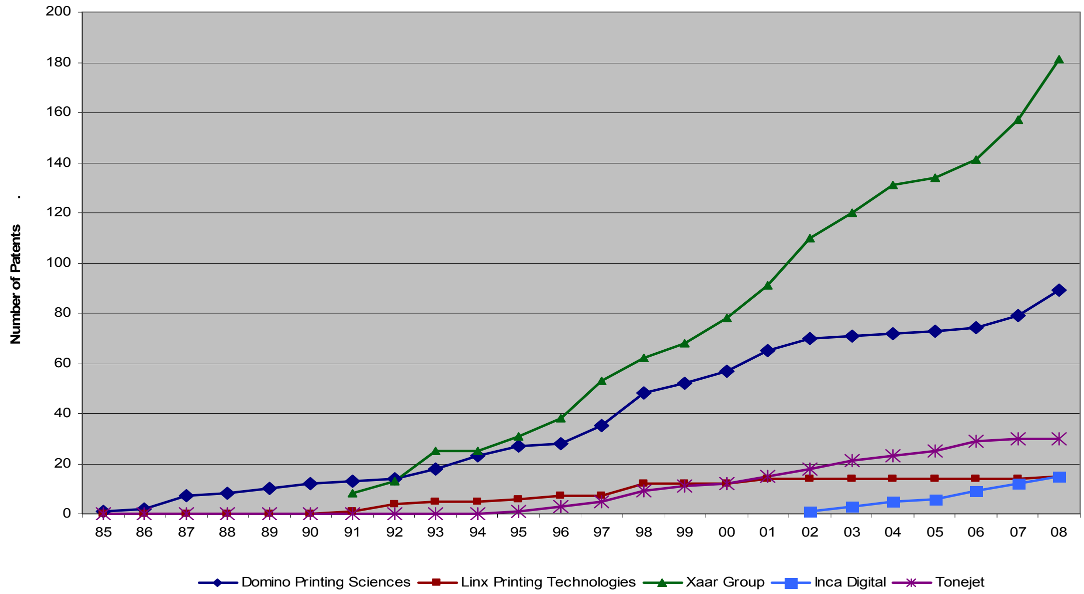

Figure 1: Cumulative Patents for the Cambridge Inkjet Printing companies

The market for the application of inkjet technologies has divided into a number of sectors as the industry has evolved and firms have made a considerable effort to renew their technologies. Whereas advances in technology have had the potential for new markets these have often been used to improve efficiency in existing markets. The development of wide web drop-on-demand technologies is an example of this. These have had early success in basic label printing applications although they were anticipated to revolutionise printing and publications markets. The inkjet printing technologies are now being applied to ever more diverse areas. For example, one application is in the production of printed circuit boards where the very precise delivery of conducting material onto an insulating substrate material is required.

Literature review

The paper investigates patents as a proxy indicator of core competences with regard to the Cambridge inkjet printing (IJP) cluster. Core competences have been described as “a bundle of skills and technologies” by Hamel and Prahalad (1994, p. 2002). They have also been defined as a pool of experience, knowledge and systems that can act together as a catalyst to create and accumulate strategic assets that are new ((Markides and Williamson, 1994). A company’s competitive advantage will be constituted of strategic assets that are imperfectly imitable (Duysters and Hagedoorn, 2000). Developed within companies core capabilities can be associated with search routines and skill sets (Nelson, 1991). They can also be related to specialisation of refocusing within firms in relation to a set of capabilities (Hoskisson and Hitt, 1994).
This study of the analysis of patents as a proxy indicator of core competences has concentrated on the IJP cluster in Cambridge. The IJP cluster has been established with international competition and a dynamic global environment has developed with requisite competences that firms need to successfully compete. Since this is a high tech cluster core competences are associated with technological skills that differentiate firms (Duysters and Hagedoorn, 2000). Two issues are identified by Duysters and Hagedoorn (2000) as critical in the understanding of core competences and these are the breadth and degree of specialisation and the sophistication and depth of core competences. Accordingly there are a number of aspects of core competences creational to differential firm performance.
It is the proposition of this paper that the level of technological sophistication or specialisation of IJP companies can be determined through patent statistics (Duysters and Hagedoorn, 2000). Patents are an acceptable indicator of research output and technological competence (Patel and Pavitt, 1991; Cantwell and Hodson, 1991). Although subject to debate regarding usefulness (Cohen and Levin, 1989; Grilliches, 1990; Archibugi, 1992) patents will enable the comparison of the technological performance (Pavitt, 1988; Acs and Audretsch, 1989) of the IJP cluster companies. In general patents show that a firm has converted innovative activities and research into protectable inventions which indicates the research skills and technological track record of the firm together with technological capability (Duysters and Hagedoorn, 2000).

Research Methodology

The concentration of patents in an industrial cluster will indicate particular choices concerning the priority skills and innovative capabilities and in these terms patent specialisation of a firm’s activities will exhibit core competences and technological specialisation with regard to technological skills and the research output breadth. With regard to the depth and breadth of technological capabilities the following hypotheses are formulated in accordance with Duysters and Hagedoorn, 2000).

Hypothesis 1

Degree of technological sophistication of a company in terms of patent activity is an important dimension of the depth of core competence and is expected to have a positive relationship to performance.

Hypothesis 2

Degree of technological specialisation of a company in terms of patent specialisation is an important indicator of the breadth of core competence and is expected to have a positive relationship to performance.

It can be inferred from classical discussion in the innovation literature that the size of companies influences patenting behaviour (Scherer, 1965; 1984). Patent specialisation can be considered to be an indicator of technological specialisation and breadth of technological capabilities and it is possible to compare the ratio of IJP patent applications to total applications for each IJP firm.

Hypothesis 3

The size of the Inkjet Printing company will influence patenting behaviour in terms of patent specialisation as an indicator of technological specialisation and breadth of technological capabilities.

A ratio close to 1 will indicate that a firm concentrates its patents mainly in inkjet printing whereas a ratio close to 0 will indicate that patents of IJP firms will be applied to other fields.

Hypothesis 4

For the IJP companies a ratio close to 1 will indicate that it concentrates its patents mainly in inkjet printing whereas a ratio close to 0 indicates that patents will be applied to other fields.

For patent activity as an indicator of technological sophistication and depth of technological capability the total number of patent applications for each firm can be normalised by the firm size.
The case study research used a number of sources to gather information including interviews, academic reports, company brochures, news releases, company Web sites and the Worldwide esp@cenet patent database. Seven in-depth case studies were undertaken with Inkjet Printing companies at different stages of development (see Table 1). These included Domino Printing Sciences, Biodot Ltd, Inca Digital, Linx Printing Technologies, Xaar Group, Xennia and Inkski Ltd.
The next section, Case Study Findings, condenses interviews with these companies into short summaries of recurrent themes among a sample of industrial ink jet printing companies.

Table 1: List of case study Inkjet Printing companies

Company	Number of employees	Time in business	Turnover (£ million)
Domino Printing Sciences	550	30 years	231.5
Biodot Ltd	4	14 years	Unknown
Linx Printing Technologies	718	21 years	52.1
Xaar Group	250	18 years	30.0
Xennia	30	12 years	3.5
Inca Digital	100	7 years	18.0 (est.)
Inkski Ltd	1	14 years	Unknown

Case Study Findings and Analysis

The case study research findings for the seven Ink Jet Printing companies are given below.

Domino Printing Sciences www.domino-printing.com

Background and history

Domino was built around products utilising single jet inkjet technology, with CCL continuing to develop multi-jet versions. In its infancy Domino was supported and nurtured by CCL and development work continued to be undertaken for them following spin off. A licence agreement allowed the company to non-exclusive access to CCL know-how and patents enabling it to manufacture and sell inkjet systems. In return CCL received royalties on sales of all Domino products and CCL was entitled to grant licences to other companies if sales fell below a certain threshold (Domino was obliged to offer CCL 'first refusal' on development programmes for further inkjet products).

Domino's machines consist of a collection of electronics which guide the ink nozzles and, because they are operated by electro-magnetic impulses and not by compressed air, the machine can be installed in a small metal or plastic cabinet. The essential elements of the machine are the microprocessors and their development and Domino has spent most of its time developing this part of the business rather than the construction of the machines.

Patent activity

Approximately 93 patent results were found on the Worldwide esp@cenet database for Domino Printing Sciences. From these 63 concerned inkjet printing and 30 were in other or related areas. This gives a figure of 0.6774 or approximately 0.7 as the ration of inkjet printing patents to reported patents for the company.

BioDot Ltd www.biodot.com

Background and history

The smallest of the inkjet printing companies in the area BioDot only has a small number of employees and was founded as a spin-out from Domino in 1994. The company supplies non-contact nanoliter and low microliter dispensing equipment for

the development and manufacture of BioChip Arrays, Biosensors and Rapid Diagnostic test devices. The core technology is descended from ink jet printing.
The company was formed following Philip Shaw, an employee of Domino Printing Sciences, taking redundancy who concluded an agreement with Domino granting him access to Intellectual Property (IP) relating to enzyme printing. It was agreed that the company would not produce inkjet printers and Domino would supply components and not produce enzyme printers. In March 1990 Biodot commenced trading and included Selwyn Image a colleague at Domino who took a 5% stake in the business, but left soon afterwards moving to Willet, a Cambridge based inkjet manufacturer, since he found himself more suited to working in a large business.

Patent activity

From 8 patent results found on the Worldwide esp@cenet database for BioDot only 1 patent was in the inkjet printing area with 7 in other or related areas. This provides a figure of 0.125 or 0.1 as the ration for inkjet printing patents to reported patents for the firm.

Linx Printing Technologies plc www.linx.co.uk

Background and history

Linx Printing Technologies plc was founded in 1987. It has about 718 employees and it had estimated revenues of £52.1m in 2004. It is in the marking and coding area of the industrial inkjet printing sector that the company is involved, particularly the manufacture and marketing of ink jet and laser coders to a range of global industry sectors including food, beverage, pharmaceutical, and industrial customers for 'on-line' variable information marking/coding. The company has five locations with two sites in the UK (St Ives and Hull), one in France, one in the USA and two in China.
Linx Printing Technologies was founded by M.R.Keeling and H.Weinberg, who were formerly on the Cambridge Consultants ink jet team, to exploit legislation driven marking/coding opportunities in the United Kingdom (UK) and the European market at the end of the 1980s/early 1990s. Linx Printing Technologies has been a developer of industrial coding and marking equipment, based on inkjet and laser technologies, used to print variable information such as serial numbers and 'sell-by' dates on products and product packaging at manufacturing line speeds. By operating through direct subsidiaries, representing 50% of total revenues, and a Worldwide network of specialist distributors, Linx has served a global customer base in a wide range of manufacturing industries including beverage, food and pharmaceuticals. The company holds a significant and increasing World wide market share as a key player in both the inkjet and laser coding industries with products sold to companies across the globe.

Patent activity

Approximately 55 patents were found in the Worldwide esp@cenet database for Linx. Out of these 11 were found to be concerned with inkjet printing and 44 in other or related areas. This gives a figure of 0.2 for the ration of inkjet printing patent to reported patents for the company.

Xaar Group plc www.xaar.co.uk

Background and history

The Xaar Group plc was founded in 1990. There are about 250 employees with revenues of £30m in 2004. The main sector of work is printing, ink jet, wide format graphics (posters), involving the design and manufacture of ink jet print heads. There

are two site locations with prototyping in Cambridge and volume manufacturing in Sweden, and four sales offices with two in China and one each in Japan and the USA.
The Xaar Group plc was spun out from CCL in 1990 and although the initial business plan was for licensing only this has now been transformed to manufacturing since licensing only was not sustainable. Competition now is mainly from own licensees, but Spectra in the USA is also in the same markets and the main challenge from 2005 has been to expand into new markets.

Patent activity

From 15 patents results considered for Xaar found on the Worldwide esp@cenet database 12 were in the area of inkjet printing and 3 in other or related areas. This results in a figure of 0.8 for the ration of inkjet printing patents to reported patents for the company.

Xennia Technology Ltd www.xennia.com

Background and history

Xennia was founded in April 1996. There are 30 staff and it had an estimated value of £2.2m in both 2002 and 2003 and £3.5m in 2004. The company is in the industrial ink jet, chemistry layered integrator sector and its activities include new solutions for manufacturing companies, starting from fluids to provide solutions in hardware and software for specific applications. The firm has one site at Royston.
Xennia was founded by Alan Hudd, ex Domino ink and R&D group leader who saw an opportunity in industrial ink jet from the drop on demand (DOD) techniques that were being developed. The company was founded to provide ink formulation for DOD, although the background of the founder was continuous ink jet (CIJ). There is an ultimate selling point of a unique level of ink jet formulation, which is uniquely a one-stop shop to acquire an integrated customised solution to have inks, hardware and software as a total package. The firm has a unique breadth and knowledge of all print head types.

Patent activity

The 10 patent results found on the Worldwide esp@cenet database for Xennia shows 9 patents as inkjet printing with only 1 in another or related area. There is therefore a figure of 0.9 for the ratio of inkjet printing patents to reported patents.

Inca Digital Printers Ltd www.incadigital.com

Background and history

Inca Digital Printers Ltd was founded in 2000. It has around 100 employees and it had estimated sales of £18m in 2004 (2003 £10m). It is in the industrial inkjet printing sector, in particular wide format, and flatbed machines. The company has one main site located at Cambridge.
Will Eve and Bill Baxter who were the founders, spun out Inca from Cambridge Consultants Ltd. The business idea was to sell high end assembled printers through ink distributors, while retaining an excellent set of engineers to build machines. The founders believed the ultimate selling point was in the "art" of assembly of super fast, efficient wide format machines. They regarded it as an art, since empirical methods were still used, rather than fluid mechanical mathematical models, and since engineering and assembly are reliant upon the jetting of inks, they too are an "art" in this case.

The idea behind Inca Digital came from the customers and it was therefore a demand driven business. When the founders were at CCL, customers enquired if it was possible to print packaging at the end of production lines. Following this a sample printer was made and it was exhibited at Ipex 1998, when it became obvious that there was a clear opportunity to develop machines for the display and signage markets. Inca's research and development (R&D) roots have continued to play an important role in the business. The successful combination of R&D with commercial awareness explains the success that Inca Digital has already had.

Inca Digital's strength is in the core technology for industrial inkjet printers and it needs partners in all its markets to help it define what customers need to take the product to market. It uses existing equipment (for handling the product into and out of its printer) so that it can supply core print engines to its OEM partners.

Inca does not rely on intellectual property rights (IPR) to protect and build market share since it takes out patents where useful but it always underplays them.

Patent activity

From the 16 patent results found on the Worldwide esp@cenet database 11 were in the area of inkjet printing and 5 in other or related areas. This gives a figure of 0.6875 or approximately 0.7 as the ration of inkjet printing patents to reported patents for the company.

Inkski Ltd www.inkski.com

Background and history

Inkski Ltd was founded in 2004 by Dr. Daniel Hall, who following his PhD degree in Computing Science at the University of Cambridge had the idea of designing an innovative digital print head which was initiated by his observation on ink drop ejection. The company then developed its unique LILO (Light Initiated Liquid Output) technology and obtained a series of patents.

Inkski Ltd's technology has attracted the interest of a number of players in the Inkjet printing industry which has helped the company to build a collaborative partnership and commercial contacts with companies such as FujiFilm and ManRoland. Since then the company has faced challenges in its technology development and market target, both of which have restricted its attractiveness to micro funds investors and potential customers. In relation to the company's evolution and analysis of its outlook, key breakthrough and demonstration of technology is considered to be the most important driver of future funding and long-term success of the business.

Following the company being founded it received initial funding from the Providence Investment Company in early 2004 and formal development and exploration of LILO (Light Initiated Liquid Output) started. The company then went through another three rounds of venture capital funding, bringing the total institutional investment to £635,000. Inkski's main investors included Providence Investment Company, Xaar plc, NESTA Ventures, GEIF Ventures and business angels. The company also obtained a Research and Development (R&D) grant of £60,000 from EEDA (East England Development Agency) in early 2005.

By early 2005, a lab/workshop space had been established in a light industrial unit and with a laser module installed. Later in 2005 EEDA confirmed a grant of £60,000 which reflected support from the Agency and indicated positive feedback from the Patent Office on the company's application. By late 2006 Inkski started testing its system with a pico-second laser. By late 2007 the company demonstrated the controlled ejection of conventional black pigmented ink onto a paper substrate

In early 2004 Daniel Hall observed that ink drops can be transported in, and then ejected from, an immiscible carrier liquid, with the carrier liquid imparting all the necessary momentum and direction to the transported ink drop. From this simple observation, the ideas behind Inkski's technology evolved. With help from contacts in the University of Cambridge Cavendish Laboratory and initial funding from Providence Investment, Inkski was set up and the formal development and exploration of the LILO technology was initiated.
Towards the end of 2007 the company had four patents covering its technology and intends to apply for more as a result of further research and development. The patent plan had delayed the pace to scale up as well as the progress of prototypes.
Patent activity
The 5 patent results found on the Worldwide esp@cenet database showed 4 as being inkjet printing and 1 in other or related areas. This gives a figure of 0.8 as the ration of inkjet printing patents to reported patents for the company.

Conclusions

According to Duysters and Hagedoorn (2000) due to the short term effects of core competences, the complex nature of modern technology and difficulties of the transfer of technological knowledge appears to favour internal development rather than external competence appropriation. They relate that technological specialisation in the form of protected and established capabilities and proven track record through a focused patent position appears to be more significant than technological performance. The results found on the Worldwide esp@cenet patent database for the IJP case study companies are shown in Table 2.

Table 2: Inkjet Printing patents for the IJP case study companies

Company	No of Inkjet Printing patents	No of other or related patents	Ratio of Inkjet Printing patents	Ratio of other or related patents	Total No of Reported Patents
Domino Printing Sciences	63	30	0.7	0.3	93
Biodot Ltd	1	7	0.1	0.9	8
Linx Printing Technologies	11	44	0.2	0.8	55
Xaar Group	12	3	0.8	0.2	15
Xennia	9	1	0.9	0.1	10
Inca Digital	11	5	0.7	0.3	16
Inkski Ltd	4	1	0.8	0.2	5
Total for IJP companies	111	91	0.55	0.45	202

Source: Worldwide esp@cenet patent database, 2008

The table shows that out of a total of 202 patents there were 111 inkjet printing patents and 91 other or related patents reported for the IJP companies which gives ratios of 0.55 for inkjet printing patents and 0.45 for patents in other or related areas.

Out of the 7 case study companies 5 had a ratio of 0.7 to 0.9 of inkjet printing patents to the total number of reported patents. This indicates that 5 of the firms concentrated their patents mainly in inkjet printing. The other two companies with ratios of 0.9 and 0.8 for patents in other or related areas indicates that that their patents were applied to other fields. The concentration of patents in the IJP cluster indicates particular choices concerning the priority skills and innovative capabilities and in these terms patent specialisation for the IJP firm's activities exhibit core competences and technological specialisation with regard to technological skills and the research output breadth.

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